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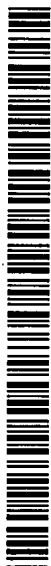


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(54) Title: METHOD AND SYSTEM FOR ARCHIVING MEDICAL IMAGES

(57) Abstract: A method, and an associated system, for acquiring and archiving images of the body of a patient. The system includes an imaging device, such as an ultrasound probe, for acquiring the images; a tracker for measuring the position and orientation of the imaging device relative to a frame of reference; a memory for storing a map of a surface of the body relative to the frame of reference; and a display unit for displaying the images along with visual or textual indications of their positions and orientations relative to the body. Optionally, the system includes a stylus for digitizing the surface to provide the map; alternatively, the imaging device itself is used as a stylus. The system also includes a tracker for measuring the position and orientation of the patient, both as the map is digitized and as the images are acquired. As the images are acquired, they are annotated with respective indications of the corresponding positions and orientations of the imaging device relative to the body, to facilitate a subsequent medical procedure with reference to the images.

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## METHOD AND SYSTEM FOR ARCHIVING MEDICAL IMAGES

FIELD AND BACKGROUND OF THE INVENTION

5       The present invention relates to medical imaging and, more particularly, to a method and system for archiving images of a patient's body that are acquired freehand.

Medical procedures commonly are performed with reference to images of the patient's body. In many such procedures, the images are acquired interactively in the  
10       course of the performance of the medical procedure. See, for example, Ben-Haim et al., WO 97/29682, which describes the guiding of a biopsy needle to targeted tissue with the aid of ultrasound images.

Two prior art references of particular note in this context are Gilboa et al., WO 00/10456 and WO 00/16684, both of which documents are incorporated by reference  
15       for all purposes as if fully set forth herein. WO 00/10456 teaches intra-body navigation of a probe in conjunction with imaging by a C-mount fluoroscope. WO 00/16684 teaches the use of a representational imaging device, such as an ultrasound probe, in conjunction with the C-mount fluoroscope of WO 00/10456, for the purpose of identifying and recording points-of-interest, within the body of the patient, towards  
20       which the probe subsequently is navigated. Figure 1, which is adapted from Figure 2 of WO 00/16684, shows a patient 24 lying on an operation platform 34 and being imaged by a C-mount fluoroscope 22. A catheter 26 is navigated within a body cavity 28 of patient 24. This navigation is enabled by the provision of a transmitter 30 of electromagnetic radiation under platform 34, a receiver 40 of electromagnetic  
25       radiation rigidly attached to fluoroscope 22, and a receiver 32 of radiation rigidly attached to catheter 26, all three of which are connected by wires 51 to a computer 50. Fluoroscope 22 is used to acquire an image of a portion of the body of patient 24 that includes body cavity 28. As explained in WO 00/10456, transmitter 30 defines a reference frame, and the signals received by computer 50 from receivers 40 and 32 in  
30       response to the electromagnetic radiation transmitted by transmitter 30 are indicative of the positions and orientations of fluoroscope 22 and catheter 26 relative to the reference frame. Given these positions and orientations, computer 50 displays, on a

display unit 48, the image of body cavity 28 acquired by fluoroscope 22, with an icon representing catheter 26 superposed on the image in the true position and orientation of catheter 26 relative to body cavity 28.

Because patient 24 may move, relative to platform 34, during the medical  
5 procedure, patient 24 also is provided with a receiver 38 of electromagnetic radiation. Computer 50 computes, from the signals received from receiver 38 in response to the electromagnetic radiation transmitted by transmitter 30, the position and orientation of the body of patient 24 relative to the reference frame. This is in addition to the computation, by computer 50, from the signals received from receiver 40, of the  
10 position and orientation of fluoroscope 22 relative to the reference frame, and in addition to the computation, by computer 50, from the signals received from receiver 32, of the position and orientation of catheter 26 relative to the reference frame. Computer 50 records the position and orientation of patient 24 when the image of body cavity 28 is acquired. If patient 24 does moves, computer 50 adjusts the joint  
15 display of the image and the catheter icon on display unit 48 to reflect the movement of patient 24, so that the catheter icon always is displayed in a manner that reflects the true position and orientation of catheter 26 relative to body cavity 28.

As alternatives to receivers 32 and 44, catheter 26 and patient 24 are provided with respective imageable markers 46 and 44. Computer 50 locates the shadows of  
20 markers 46 and 44 in the image, using standard image processing techniques, and computes, from the positions of these shadows, the positions and orientations of catheter 26 and patient 24.

A supplementary imaging device 52, equipped with a receiver 40a of electromagnetic radiation, also is provided, to acquire a supplementary image of a  
25 portion of the body of patient 24 that overlaps with the portion of the body of patient 24 that is acquired using fluoroscope 22. Computer 50 computes, from the signals received from receiver 40a in response to the electromagnetic radiation transmitted by transmitter 30, the position and orientation of imaging device 52 relative to the reference frame. Computer 50 then displays the supplementary image, on display unit  
30 48, superposed on the image acquired by fluoroscope 22, so that a point-of-interest, towards which catheter 26 is to be navigated, can be picked on display unit 48, even prior to the introduction of catheter 26 into body cavity 28. Improved methods of

effecting this superposition are taught by Gilboa et al. in WO 01/12057. Because computer 50 tracks the movement of both patient 24 and catheter 26, an icon representing the point-of-interest is displayed on display unit 48 in a manner that represents the true position of the point-of-interest in body cavity 28, so that catheter 26 can be navigated to the point-of-interest with reference to the relative positions, as displayed by display unit 48, of the icon representing catheter 26 and of the icon representing the point-of-interest. Typically, supplementary imaging device 52 is an ultrasound probe, and the supplementary image is a two-dimensional ultrasound image.

Often, however, the images are not acquired interactively. Instead, the images are acquired by an operator of an imaging device, and the medical procedure is performed at a later time by another person, a physician, who was not present during the acquisition of the images. In such a case, either the images are acquired from a standard view, or text is added to the images to explain the acquisition orientation of the images. Even with such textual explanations, it often is not easy for the physician to visualize mentally the portion of the body that is described in any particular image. Furthermore, because the textual information is based on the operator's subjective impression of the acquisition orientation, the textual information may not be sufficiently accurate for the physician's use.

There is thus a widely recognized need for, and it would be highly advantageous to have, a method of acquiring and archiving medical images, such as ultrasound images, to facilitate the comprehension and use of these images by a physician.

## SUMMARY OF THE INVENTION

According to the present invention there is provided a method of archiving an image of a body of a patient, including the steps of: (a) simultaneously: (i) acquiring the image, using an imaging device that includes a first tracker for measuring a position and orientation of the imaging device relative to a frame of reference, and (ii) measuring the position and orientation of the imaging device relative to the frame of reference, using the first tracker; (b) providing an indication of a position and orientation of the body relative to the frame of reference when the image is acquired;

(c) inferring, from the measured position and orientation of the imaging device and from the indicated position and orientation of the body, a position and orientation of the imaging device relative to the body; and (d) operationally associating with the image an indication of the position and orientation of the imaging device relative to the body.

According to the present invention there is provided a system for archiving an image of a body of a patient, including: (a) an imaging device for acquiring the image; (b) a first tracker for measuring a position and an orientation of the imaging device relative to a frame of reference; (c) a memory for storing an indication of a position and orientation of the body relative to the frame of reference; and (d) a processor for: (i) inferring, from the measured position and orientation of the imaging device and from the indicated position and orientation of the body, a position and orientation of the imaging device relative to the body, and (ii) operationally associating with the image an indication of the position and orientation of the imaging device relative to the body.

Although the present invention is described herein with reference to medical applications, it should be understood that the scope of the present invention includes veterinary applications. Thus, the patient that constitutes the "workpiece" of the present invention may be either a person or an animal.

In the context of the present invention, an "image" is a dataset that represents a portion of the interior of the patient, and not a dataset that represents a portion of the exterior of the patient. Thus, for example, an ultrasound slice, a CT volume, and a MRI volume are examples of images, whereas a photograph of the patient is not considered an "image". The scope of the term "image" in the context of the present invention includes both visual representations of a portion of the interior of the patient and digital datasets from which such visual representations can be reconstructed by appropriate means. Certain representations of the exterior of the patient, specifically, datasets of coordinates of points on the surface of the patient's body, and other point coordinates obtained by interpolation, are considered herein to be "maps" of the surface of the patient's body.

The present invention is directed towards medical images that are to be stored after acquisition and retrieved at a later time for use in medical procedures. In the

context of the present invention, "archiving" such a medical image means formatting the image to facilitate that later use by a person such as a physician who was not present during the acquisition of the image.

According to the present invention, an imaging device such as ultrasound probe 52 is provided with a tracker such as receiver 40a. A "tracker", in the present context, is a device that is used to determine the position and orientation of the imaging device relative to a frame of reference. For example, as discussed above, receiver 40a is used to determine the position and orientation of ultrasound probe 52 relative to the frame of reference defined by transmitter 30. Specifically, the tracker is used to measure the position and orientation of the imaging device relative to the frame of reference while the image is being acquired. An indication of the position and orientation of the patient's body relative to the frame of reference while the image is being acquired also is provided. The two positions and orientations are combined mathematically to yield the position and orientation of the imaging device relative to the patient's body. An appropriate indication of this position and orientation of the imaging device relative to the patient's body is included with the image to facilitate the image's subsequent use by a physician who was not present when the image was acquired.

Preferably, the imaging device is an ultrasound probe.

Preferably, the indication of the position and orientation of the imaging device relative to the patient's body is a visual indication. In the present context, a "visual" indication can be either a visible image or a dataset, such as a digital dataset, from which such a visible image can be reconstructed by appropriate means. Alternatively, the indication of the position and orientation of the imaging device relative to the patient's body is a textual indication. The advantage of the textual indication of the present invention over the textual indication of the prior art is that the textual indication of the present invention, being based on a direct measurement of the position and orientation that it purports to describe, is guaranteed to be sufficiently accurate for subsequent use.

As discussed above, it is an object of the present invention to facilitate the performance of a medical procedure with reference to the acquired image or images, subsequent to and independent of the acquisition of the images, and even in a separate

location from the location in which the images were acquired. To this end, the medical procedure is performed with reference to the indication of the position and orientation of the imaging device relative to the patient's body.

Preferably, the indication of the position and orientation of the patient's body  
5 relative to the frame of reference includes a map of at least a portion of the surface of the patient's body. Such a map typically is a collection of coordinates, in the frame of reference, of points on the surface of the patient's body. Preferably, such a map is provided by steps including digitizing at least three points on the surface of the patient's body. Preferably, this digitizing is effected using a stylus that includes its  
10 own tracker for measuring the position and orientation of the stylus relative to the frame of reference, so that the digitizing is relative to the frame of reference. In fact, the imaging device itself may be used as the stylus. To increase the accuracy of the map, the digitized points are supplemented by interpolating the coordinates of points between and among the digitized points.

15 The patient may move during this mapping procedure. Therefore, most preferably, yet another tracker is secured to the patient's body, and the position and orientation of the patient's body relative to the frame of reference are measured using this additional tracker. The coordinates of the digitized and interpolated points are updated in accordance with the measured movement of the patient to ensure the  
20 accuracy of the indications of the positions and orientations of the imaging device, relative to the patient's body, that are associated with images acquired subsequent to the movement of the patient.

A system of the present invention includes the imaging device, a first tracker for measuring the position and orientation of the imaging device relative to the frame  
25 of reference, a memory for storing an indication of the position and orientation of the patient's body relative to the frame of reference, and a display unit for displaying images acquired by the imaging device along with the associated indications of the position and orientation of the imaging device relative to the patient's body. Preferably, the imaging device is an ultrasound probe.

30 Preferably, the system also includes a stylus for digitizing points on the patient's body to provide at least a portion of the map. This stylus may be included in the imaging device.

Preferably, the system also includes a second tracker for measuring the position and orientation of the patient's body, in case the patient moves while the images are being acquired.

5 BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 illustrates a prior art system for intra-body navigation of a catheter within the body of a patient, with reference to images acquired by a fluoroscope and  
10 an ultrasound probe;

FIG. 2 is FIG. 1 modified to illustrate a system of the present invention;

FIGs. 3, 4, 5a and 5b are exemplary visual indications of positions and orientations of acquired ultrasound images.

15 DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a medical imaging method and system which can be used to acquire images of the body of a patient in a form suitable for archiving. Specifically, the present invention can be used to facilitate the performance of a medical procedure with reference to images acquired prior to, and independently of,  
20 the medical procedure.

The principles and operation of archival medical imaging according to the present invention may be better understood with reference to the drawings and the accompanying description.

Referring again to the drawings, Figure 2 is Figure 1 modified to illustrate a  
25 system of the present invention. Fluoroscope 22, receiver 40, the associated wires 51, and markers 44 and 46 have been removed. Reference numeral 52 now designates the sole imaging device, specifically, an ultrasound probe. As in Figure 1, reference numeral 40a designates a receiver of electromagnetic radiation that is rigidly attached to probe 52 and that is used as a tracker to measure the position and orientation of  
30 probe 52 relative to the common frame of reference defined by transmitter 30. Tracker 40a and probe 52 are connected by their own wires 51 to computer 50, just as fluoroscope 22 and receiver 32 are connected to computer 50 in Figure 1.



In the system illustrated in Figure 2, probe 52 also serves as a stylus that is used to digitize representative points on the surface of patient 24, for the purpose of constructing a map of the portion of that surface that is relevant to displaying the images acquired using probe 52. Because tracker 40a is rigidly attached to probe 52, the position and orientation of tracker 40a relative to a reference point on the housing of probe 52, such as a distal tip 56 of probe 52, is known. Therefore, the coordinates of tip 56 in the common frame of reference can be inferred from the measured position and orientation of tracker 40a. The coordinates of points on the surface of patient 24 are measured by touching tip 56 successively to those points while measuring the position and orientation of tracker 40a. This process of measuring the coordinates of these surface points is termed herein "digitizing" these surface points. The digitized points are stored in a memory 54 that is operatively associated with computer 50.

Alternatively, a separate stylus, such as the MicroScribe, available from Immersion Corp, San Jose CA, is used to digitize representative points on the surface of patient 24. The MicroScribe is a mechanical stylus which must be positioned and oriented separately relative to the common frame of reference defined by transmitter 30. For example, the MicroScribe may be positioned and oriented relative to the common frame of reference by digitizing three fiducial points on an object having a known, fixed position and orientation in the common frame of reference.

If the combination of probe 52 and tracker 40a is used as the digitization stylus of the present invention, then the digitization stylus of the present invention is said to be included in probe 52, in the sense that in addition to the physical structure of the housing of probe 52, which housing then constitutes the body of the stylus, probe 52 also includes the hardware, such as one or more piezoelectric transducers and the associated electronics, that is used to acquire the ultrasound images that are the primary *raison d'être* of probe 52.

The position and orientation of the body of patient 24 relative to the common frame of reference also is measured, using tracker 38. In case patient 24 moves during the digitization process, the new position and orientation of the body of patient 24 relative to the common frame of reference is measured using tracker 38, and the mathematical transformation that transforms the old measured position and

orientation of the body of patient 24 to the new position and orientation of the body of patient 24 is applied to the coordinates of the map points that were acquired prior to the movement of patient 24, to keep the map internally consistent.

As noted above, the preferred indications of the position and orientation of probe 52 relative to the body of patient 24 are visual indications. To this end, sufficient points on the surface of patient 24 are digitized to enable the display of a map of the relevant portion of the surface in sufficient detail to indicate, to a physician, the position and orientation, relative to the body of patient 24, of the images acquired using probe 52.

The map having been acquired, the desired images of the body of patient 24 are acquired, using probe 52. As each image is acquired, the corresponding position and orientation of probe 52 are measured using tracker 40a, and the corresponding position and orientation of the body of patient 24 are measured using tracker 38. These positions and orientations are stored along with the images in an archival image database in memory 54.

Alternatively, instead of acquiring a surface map of patient 24, a standard map is stored in memory 54, and patient 24 is instructed to lie on platform 34 so that the standard map constitutes an approximate rendition of the position and orientation of the surface of the body of patient 24 relative to the frame of reference defined by transmitter 30. Such a standard map is sufficiently accurate for archival purposes relative to some subsequent medical procedures.

At a later time, a physician who desires to perform a medical procedure on patient 24, with reference to the archived images, uses computer 50 to retrieve those images, as needed, from memory 54 and to display those images on display unit 48. Each displayed image is accompanied by a visual indication of the position and orientation of that image, as acquired, relative to the body of patient 24. Display unit 48 may be a video monitor. Alternatively, display unit 48 may be a printer that generates hardcopies of the images along with the associated visual indications of the positions and orientations of the images relative to the body of patient 24.

Figures 3-5b are examples of visual indications of positions and orientations of acquired ultrasound images.

Figure 3 shows a Cartesian coordinate system superposed on the head and torso of patient 24. The corresponding ultrasound slice is in the (x,z) plane.

Figure 4 is similar to Figure 3, except that the x and y axes are represented as crosshairs, with the x axis represented by the horizontal crosshair and the y axis being  
5 represented by the vertical crosshair. The head and torso of patient 24 is represented from a viewpoint such that the x axis is horizontal, the y axis is vertical and the z axis is in-line with the viewpoint.

Figures 5a and 5b show front and side views, respectively, of the head and torso of patient 24. Superposed on these views of the head and torso of patient 24 are  
10 respective projections of ultrasound probe 52 and the location of the portion of the body of patient 24 that is imaged in the corresponding ultrasound slice 58.

The heads and torsos shown in Figures 3-5b are most simply provided as parts of the alternative standard map of the body surface, as an interactively acquired map typically does not include this much of the surface of the body of patient 24.  
15 Alternatively, both the standard map and the interactively acquired map are used, and the interactively acquired map is extrapolated by known digital fitting techniques, with reference to the standard map, to include the desired portions of the body of patient 24 that were not digitized. Note that to achieve a visually realistic rendition of a digitized map, the rendition must include interpolated points as well as the explicitly  
20 digitized points. This interpolation is effected by computer 50 using known techniques such as spline fitting.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

## WHAT IS CLAIMED IS:

1. A method of archiving an image of a body of a patient, comprising the steps of:
  - (a) simultaneously:
    - (i) acquiring the image, using an imaging device that includes a first tracker for measuring a position and orientation of said imaging device relative to a frame of reference, and
    - (ii) measuring said position and orientation of said imaging device relative to said frame of reference, using said first tracker;
  - (b) providing an indication of a position and orientation of the body relative to said frame of reference when the image is acquired;
  - (c) inferring, from said measured position and orientation of said imaging device and from said indicated position and orientation of the body, a position and orientation of the imaging device relative to the body; and
  - (d) operationally associating with the image an indication of said position and orientation of the imaging device relative to the body.
2. The method of claim 1, wherein said imaging device is an ultrasound probe.
3. The method of claim 1, wherein said indication of said position and orientation of the imaging device relative to the body is a textual indication.
4. The method of claim 1, wherein said indication of said position and orientation of the imaging device relative to the body is a visual indication.
5. The method of claim 1, wherein said acquiring of the image is effected at a first location, the method further comprising the step of:
  - (e) performing a medical procedure, at a second location, different from said first location, with reference to said indication of said position and orientation of the imaging device relative to the body.

6. The method of claim 1, wherein said providing of said indication of said position and orientation of the body relative to said frame of reference is effected by steps including:

- (i) providing a map of at least a portion of a surface of the body.

7. The method of claim 6, wherein said providing of said map is effected by steps including:

- (A) digitizing at least three points on said surface.

8. The method of claim 7, wherein said digitizing is effected using said imaging device as a stylus.

9. The method of claim 7, wherein said providing of said map is effected by steps further including:

- (B) interpolating said at least three digitized points.

10. The method of claim 6, wherein said map is relative to said frame of reference.

11. The method of claim 6, wherein said providing of said indication of said position and orientation of the body relative to said frame of reference is effected by steps further including:

- (ii) measuring a position and an orientation of the body relative to said frame of reference; and
- (iii) modifying said map in accordance with said measured position and orientation of the body.

12. The method of claim 11, wherein said measuring of said position and orientation of the body is effected using a second tracker secured to the body.

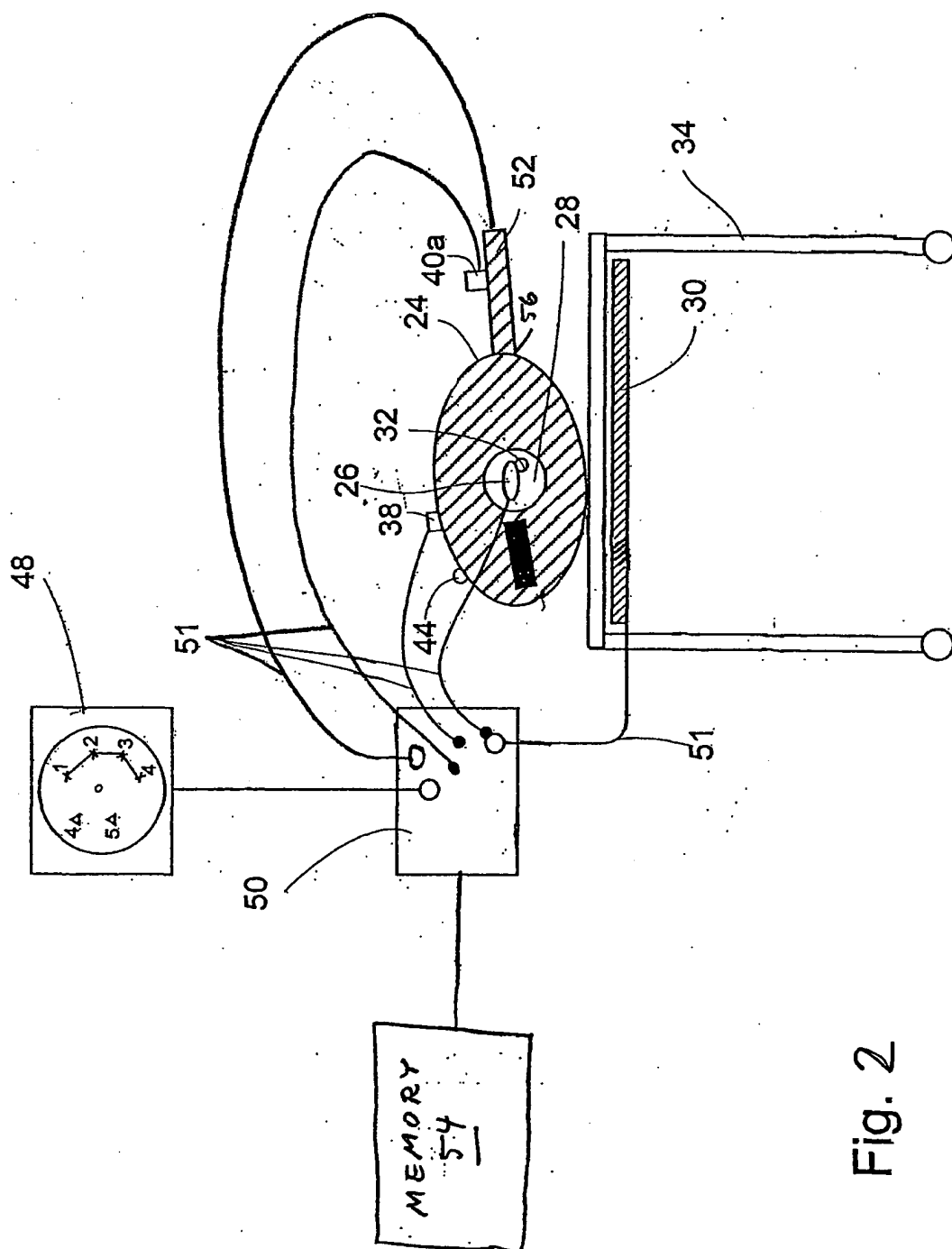
13. A system for archiving an image of a body of a patient, comprising:

- (a) an imaging device for acquiring the image;
  - (b) a first tracker for measuring a position and an orientation of said imaging device relative to a frame of reference;
  - (c) a memory for storing an indication of a position and orientation of the body relative to said frame of reference; and
  - (d) a processor for:
    - (i) inferring, from said measured position and orientation of said imaging device and from said indicated position and orientation of the body, a position and orientation of the imaging device relative to the body, and
    - (ii) operationally associating with the image an indication of said position and orientation of the imaging device relative to the body.
14. The system of claim 13, further comprising:
- (e) a display unit for displaying the image along with said indication of said position and orientation of the imaging device relative to the body.
15. The system of claim 13, wherein said imaging device is an ultrasound probe.
16. The system of claim 13, wherein said indication of said position and orientation of the body relative to said frame of reference includes a map of at least a portion of a surface of the body.
17. The system of claim 16, further comprising:
- (e) a stylus for digitizing points on the body, said points then forming at least a portion of said map.
18. The system of claim 17, wherein said stylus is included in said imaging device.

19. The system of claim 13, further comprising:
  - (e) a second tracker for measuring a position and orientation of the body relative to said frame of reference.







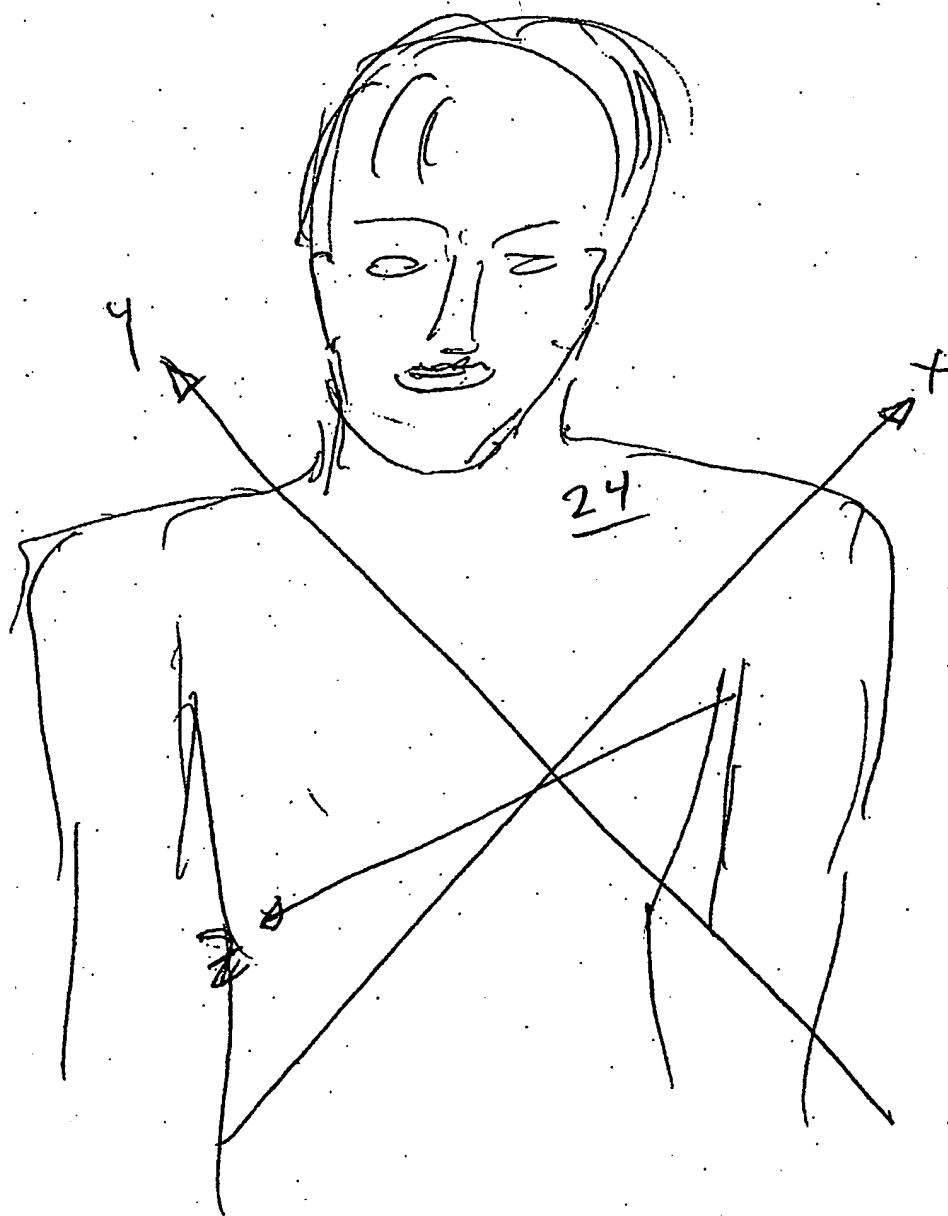


Figure 3

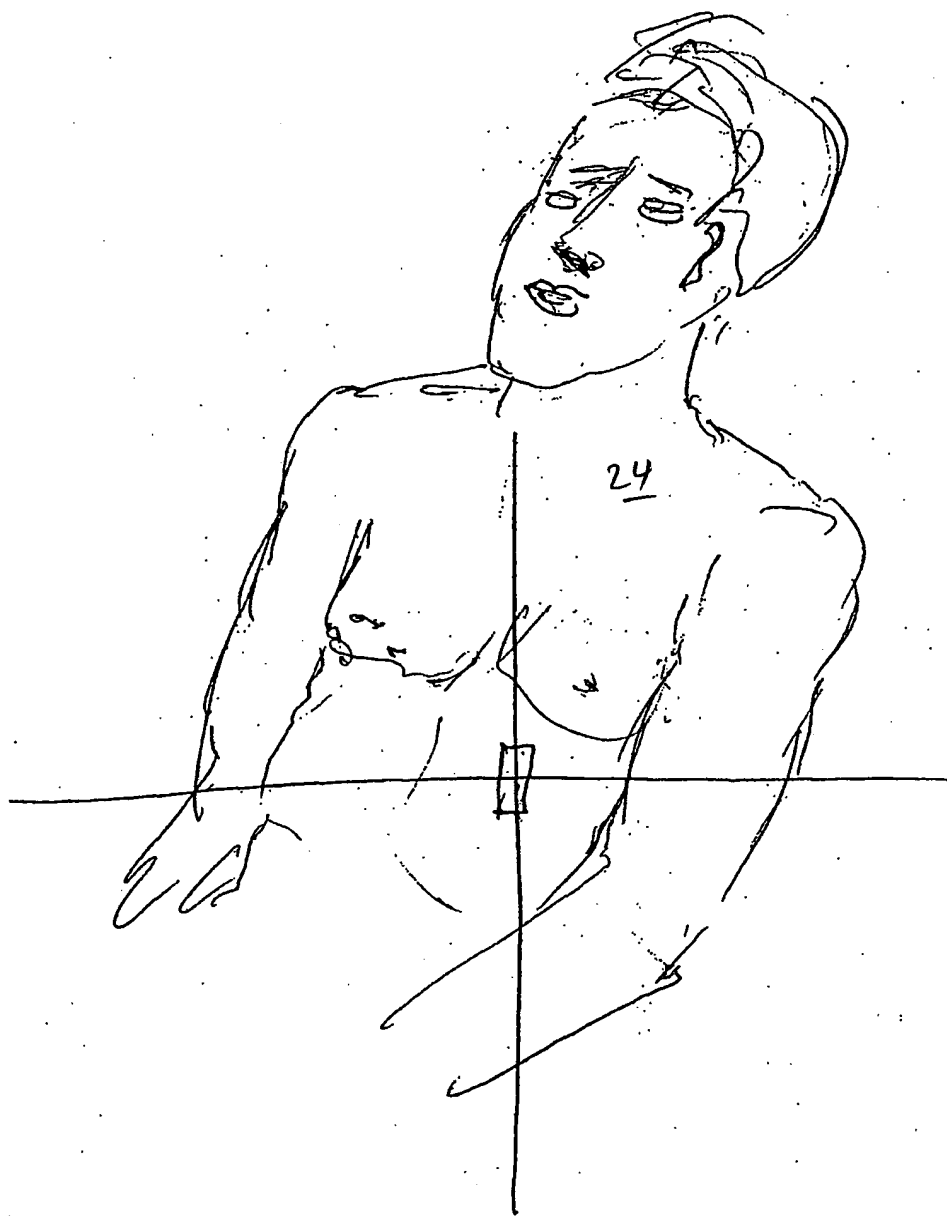


Figure 4

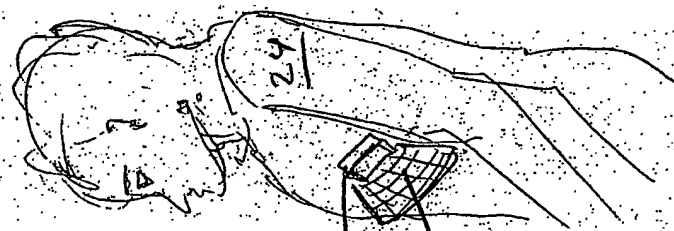


Figure 5b

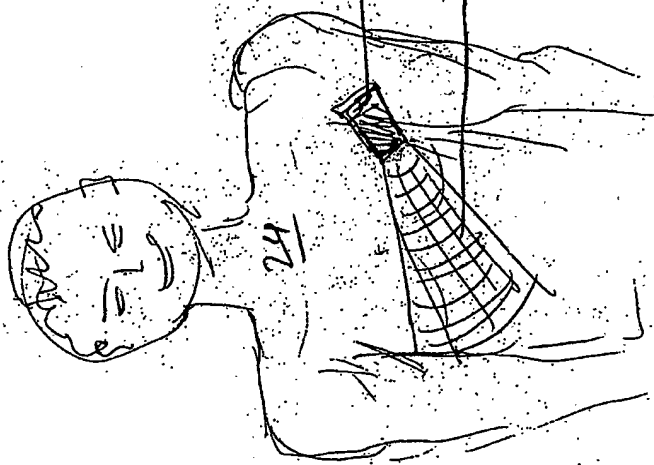


Figure 5a

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